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4T–V–W HADDOCK : RECRUITMENT AND STOCK ABUNDANCE IN 1970–72

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INTRODUCTION

A marked decline in the abundance of, and yield from, the haddock stock of the eastern Scotian Shelf and southern Gulf of St. Lawrence (ICNAF Div. 4T–V–W) necessitate consideration of further regulation of this fishery (Report of the Interim Meeting of the Assessments Subcommittee, ICNAF Comm. Doc. 70/3). An assessment of this stock is presented by Halliday (ICNAF Res. Doc. 70/74). The present document provides estimates of the abundance of the 1966–68 year-classes which will be recruited in 1970–72, and predicts the abundance of the exploited population in these years.

Data on which to predict the strength of recent year-classes are limited to that obtained on a single Canadian research vessel cruise prosecuted in 4W in July 1969. This cruise was specifically designed to quantitatively survey groundfish stocks, particularly juvenile haddock. It will, of course, be several years before the usefulness of predictions from this and subsequent cruises can be adequately evaluated. However, as predictions are required now, a cursory evaluation is carried out using pre–1969 surveys designed for other purposes. The preliminary nature of these results probably require no further emphasis.

MATERIAL AND METHODS

Dr. Frank McCracken undertook three cruises in 4V–W in the summers of 1958–60 to investigate haddock distribution. He found that small haddock ages 1–4 are concentrated on the offshore banks, mainly Sable Island Bank, at that time of year (McCracken, 1965). The results of these three cruises are used here to estimate the abundance of the 1954–59 haddock year-classes at ages 1–3, and investigate the relationship to subsequent abundance in the commercial fishery.

In the light of McCracken's results, the area considered in the following calculations is restricted to offshore 4W — specifically strata 52–55, 60–64 inclusive (Fig. 1). These strata form part of a preliminary stratification of the Nova Scotia banks agreed upon by Canadian, Soviet, and U.S. scientists for use in multi-national groundfish surveys (Grosslein, ICNAF Res. Doc. 70/80). The area covered by these strata (Table 1), calculated from large-scale fishing charts of the area, is about 9,700 square nautical miles.

The summer, 1969 survey procedure was similar to that of recent USA–USSR joint groundfish surveys, involving fishing at randomly pre-selected stations within strata, and is described and justified by Grosslein (ICNAF Res. Doc. 68/87). In contrast, on the 1958–60 cruises, stations were not randomly selected, and frequently several tows were made at the same location. However, broad coverage of the area was a major objective of the cruises, and each stratum contains at least one fishing station with the exception of stratum 64 in 1958 (Table 1). To reduce bias due to non-random station selection, repeat tows are not considered in this analysis. A repeat tow is arbitrarily defined as one starting less than 4 minutes of latitude or longitude from a previous tow, unless the average depth fished in the two tows differed by 5 fathoms or more.

TABLE 1. Strata areas and coverage by Canadian research vessel surveys.

VESSEL		HARENGUS	HARENGUS	HARENGUS	EE PRINCE	EE PRINCE
DATE		Aug-Sep'58	July '59	July '60	July '67	July '69
GEAR		#36 Manilla	#36 Manilla	#36 Manilla	#41 Polye-thylene	#36 Polye thylene
TRAWL MOUTH OPENING(feet)		35	35	35	45	35
TOWING SPEED (knots)		3.0	3.0	3.0	3.5	3.5
STRATUM	AREA (sq. naut. miles)	NUMBER OF TOWS				
52	1,837	3	6	3	2	7
53	2,002	5	9	6	5	13
54	257	6	1	1	1	2
55	1,093	4	5	5	7	6
60	584	1	2	3	1	4
61	873	1	7	2	2	3
62	831	9	6	8	10	5
63	1,779	5	8	10	11	9
64	448	-	5	2	-	4
TOTAL	9,704	34	49	40	39	53

The 1958–60 surveys were made by the M.V. *Harengus*, a 78' side trawler, using a #36 yankee manilla otter trawl. The 1969 survey was made by the C.G.S. *E.E. Prince*, a 130' stern trawler, using a #36 yankee polyethylene otter trawl. Both trawls had 1¼" codend liners or covers. No comparative fishing experiments for haddock have been conducted with these vessels. Comparative fishing for cod shows catches are comparable in numbers and length-frequency distribution when allowance is made for differences in distances travelled (Kohler, MS, 1969). It is assumed here, that the two vessels are also comparable in their ability to catch haddock.

Area of seabed swept by each tow is taken as the product of the width between the trawl wings and the distance travelled. Carrothers *et al.* (MS, 1969) indicate that the wing spread of a #36 yankee polyethylene trawl towed by the *Harengus* at 3.0 knots (the vessel's normal towing speed) is 35 feet. No gear behaviour studies have been conducted on the *E.E. Prince* but it is assumed that the wing spread of its #36 trawl is also 35 feet. Normal towing speed of the *E.E. Prince* is 3.5 knots. On the 1958 *Harengus* cruise, tows were mainly of 45 minutes duration. In subsequent cruises they were almost all of 30 minutes duration.

Total number of haddock and their lengths in each catch were recorded, or were estimated from subsamples when the catch was very large. On each survey a sample of 500–1000 otoliths were collected for age determination.

An estimate of the total number of haddock present in each stratum, and by summation, the total number in the whole area, in each year, is calculated by simple proportion:

$$\text{total number} = \text{number caught} \times \frac{\text{total area}}{\text{area swept}}$$

A single age-length key for the whole area is applied to the combined length-frequency distributions of all tows in a stratum, to provide the age distribution of the haddock in that stratum. Estimates of numbers of haddock of each age-group in each stratum are obtained by prorating the estimates of total numbers by the appropriate age distribution. Total numbers of haddock of each age in the whole area, are the sums of the numbers in each stratum.

In July 1967 McCracken undertook a survey in 4W to investigate the distribution and abundance of juvenile haddock. The vessel used, the *E.E. Prince*, was at this time equipped with a #41 yankee polyethylene otter trawl. Doubts as to the ability of the *E.E. Prince* to fish this gear efficiently resulted in a change to the smaller #36 yankee trawl after the first year of the vessel's operation (1967). Thus, less confidence can be placed in the quantitative results of the 1967 survey and these are presented with reservations. Data treatment is identical to that for 1958–60 cruises. Wing spread is taken as 45 feet, from data of Carrothers *et al.* (MS, 1969) for the #41 yankee trawl fished by other vessels.

Haddock from this stock normally make their first contribution to landings at age 3, becoming fully recruited to otter trawls using regulation 4½-inch mesh at age 6. (This is almost entirely an otter trawl fishery). In the following analysis estimates of partial recruitment of age-groups 3–5 are required. These are obtained by the method of Horsted and Garrod (1969) using 1958–61 Canadian commercial sampling data and adjusting these to represent total landings. The method involves calculating the numerical abundance (N) of

each age-group at the beginning of each year, using a single value of F (instantaneous fishing mortality) for all age-groups. Values of F used in this and other calculations are derived from the equation:

$$F = qf$$

where f is effective fishing effort (total catch/Canadian catch per unit effort) and q = 0.000 009 068 from the regression of instantaneous total mortality (Z) on fishing effort (Halliday, ICNAF Res. Doc. 70/74). Estimates of N for each age-group are made in two ways:

(1) as the survivors of the stock in year $i-1$, from the equation:

$$N_i = N_{i-1}\, e^{-Z_{i-1}} \qquad \text{——equation 1}$$

(2) as the number of fish at the beginning of the year i necessary to generate the catch (C) in that year, from the equation:

$$N_i = \frac{C_i\, Z_i}{F_i\,(1-e^{-Z_i})} \qquad \text{——equation 2}$$

The difference between these estimates represents the number of new recruits entering the age-group, and the ratio between this and the number in the stock of the year-class at the beginning of year $i-1$ measures the new recruits as a proportion of the previous stock of that year-class. The 1958–61 haddock give three observations for each pair of age-groups and the mean of these is used to calculate partial recruitment values as described in the following results section.

RESULTS

PARTIAL RECRUITMENT VALUES

Investigation of partial recruitment by the method of Horsted and Garrod confirms previous conclusions that year-classes are fully recruited to this fishery at age 6, as new recruits as a proportion of previous stock approximates zero at age-groups 7/6 (Table 2). New recruits at age 6 (R_6) to the stock at age 5 (N_5) is 0.2447. Therefore:

$$R_6 = 0.2447\, N_5$$

Also $$N_5 + R_6 = N_6$$

therefore $$N_5 + 0.2447\, N_5 = N_6$$

and $$N_5 = N_6 \,/1.2447$$

Taking $N_6 = 1$, signifying full recruitment,

then $N_5 = 0.80$

i.e. haddock at age 5 are 80% recruited to the fishery.

Similarly partial recruitment indices are calculated for age 4 = 0.41, and age 3 = 0.06. These values indicate that 50% recruitment occurs at approximately 4.2 years, close to the independent estimate of 3.8 years from net characteristics of the Canadian fleet (Halliday, ICNAF Res. Doc. 70/ 74).

TABLE 2. New recruits as a proportion of the stock of the same year-class one year earlier. (Means calculated diagonally.)

	Calendar years				
Year-class	1959/58	1960/59	1961/60	Mean	Age-groups in ratio
1949	neg.				
1950	neg.	.0510			
1951	neg.	.9379	.1155	-	10/9
1952	neg.	.0541	.0155	-	9/8
1953	.4704	.5112	.0478	-	8/7
1954	1.2036	.1050	neg.	-	7/6
1955	3.6667	.5711	.1588	.2447	6/5
1956		1.0423	1.0504	.9417	5/4
1957			14.3126	6.3405	4/3

RECRUITMENT PREDICTIONS

The 1958–60 surveys give estimates of total numbers of haddock of the 1954–59 year-classes at various ages between 1 and 4 (Table 3). The 1956 and 1957 year-classes were the most abundant, and that of 1958 least abundant, of the six. Survival of year-classes between ages 1 and 2, and 2 and 3, was about 78%, and between ages 3 and 4, about 62% (Table 4).

TABLE 3. Estimated total numbers of haddock of the 1954–59 year-classes in the survey area in the summers of 1958–60.

EAR	YEAR-CLASS					
	1954	1955	1956	1957	1958	1959
958	6,032,000	10,027,000	39,375,000	25,253,000	-	-
959	-	6,379,000	30,680,000	27,047,000	3,825,000	-
960	-	-	18,281,000	21,743,000	1,810,000	9,777,000
Age (diagonally)			4	3	2	1

TABLE 4. Survival of 1955–58 year-classes at ages between 1 and 4 from estimates of abundance in the survey area in successive years.

YEAR-CLASS	SURVIVAL (%) Age 1–2	Age 2–3	Age 3–4
1958	47	-	-
1957	107	80	-
1956	-	78	60
1955	-	-	64
Average	77	79	62

In those years haddock ages 1 and 2 were probably not subject to any significant fishing mortality, and 3 year olds were only 6% recruited to the fishery. Thus, mortality between ages 1 and 2, and 2 and 3, is an estimate of natural mortality, $M = 0.25$. This is close to the estimate of $M = 0.20$ obtained by regression of total mortality on effective fishing effort (Halliday, Res. Doc. 70/ 74). The estimate of total mortality $Z = 0.48$ between ages 3 and 4 thus suggests that fishing mortality, $F = 0.23$. In 1959 and 1960, F on fully recruited age-groups was about 0.75, giving an independent estimate of $F = 0.30$ on age 4, close to that obtained from the surveys.

The strengths of the 1954–59 year-classes are difficult to compare with their later abundance in the commercial fishery as they are based on 1, 2, or 3 estimates at different ages between 1 and 4. Thus abundance of each year-class at ages 1–3 is calculated (where not observed directly) from the direct observations and the survival rates presented above (Table 5). Using both observed and calculated abundance at ages 1–3, the mean abundance at these ages is obtained, thus putting all 6 estimates of year-class strength on a comparable basis.

The first significant contribution to the commercial catch is made at age 4 — this age-group contributing, on average, about 20% of the catch by numbers and 15% by weight. Thus recruitment predictions can perhaps most usefully be given as estimated population numbers at age 4.

Estimates of the total numbers of haddock landed at age 4 from the year-classes 1954–59 is obtained by prorating total landings using Canadian catch statistics. Estimates of initial population at age 4 is then obtained from equation 2 (Table 5).

The relationship of mean abundance at ages 1–3 estimated from survey cruises (X) to abundance at age 4 from commercial data (Y) is adequately described by a logarithmic transformation of the equation:

$$Y = a X^{b}$$

giving $\log_e Y = 1.4457 + 0.5785 \log_e X$

where units are expressed as millions of haddock (Fig. 2).

The transformed data have a significant correlation coefficient = 0.830 ($P_{0.05} = 0.811$).

Abundance estimates of 1963–68 year-classes at ages between 1 and 4 from 1967 and 1969 surveys are low, varying between 1.1 and 6.4 million fish (Table 6). However, abundance estimates of the 1966 and 1965 year-classes at ages 1 and 2 are considerably less than their respective abundances at ages 3 and 4. This confirms doubts about gear efficiency on the 1967 cruise, and 1967 data are not considered further. The 1969 abundance estimates of the 1966–68 year-classes are adjusted, again using a rate of survival of 0.78, to give mean abundance estimates at ages 1–3 (Table 7). Abundance at age 4 is estimated graphically from Fig. 2 giving 14.5 million recruits in 1970 (1966 year-class), 9 million in 1971 (1967 year-class), and 5.5 million in 1972 (1968 year-class).

TABLE 5. Abundance of the 1954–59 year-classes at ages 1–3 and mean abundance, estimated from survey cruises, and abundance at age 4 estimated from commercial statistics. (Asterisks denote values calculated using survival rates, S.)

AGE	S	YEAR – CLASS 1954	1955	1956	1957	1958	1959
1	.78	15,991,000*	16,481,000*	50,481,000*	25,253,000	3,825,000	9,777,000
2	.78	12,473,000*	12,855,000*	39,375,000	27,047,000	1,810,000	7,626,000*
3	.62	9,729,000*	10,027,000	30,680,000	21,743,000	1,412,000*	5,948,000*
4		6,032,000	-	-	-	-	-
MEAN OF AGES 1–3		12,700,000	13,100,000	40,200,000	24,700,000	2,300,000	7,800,000
ABUNDANCE AT AGE 4 (FROM COMMERCIAL STATISTICS)		16,900,000	38,500,000	30,900,000	19,500,000	5,400,000	15,600,000

TABLE 6. Estimated total numbers of haddock of the 1963–68 year-classes in the survey area in the summers of 1967 and 1969.

YEAR	YEAR – CLASS 1963	1964	1965	1966	1967	1968
1967	3,112,000	2,396,000	1,106,000	1,621,000	-	-
1969	-	-	5,536,000	6,371,000	3,717,000	1,878,000

TABLE 7. Abundance of the 1966–68 year-classes at ages 1–3 and mean abundance, estimated from survey cruises, and abundance at age 4 estimated from Fig. 2. (Asterisks denote values calculated using a survival rate of 0.78).

	YEAR-CLASS		
AGE	1966	1967	1968
1	10,472,000*	4,765,000*	1,878,000
2	8,168,000*	3,717,000	1,465,000*
3	6,371,000	2,899,000*	1,143,000*
MEAN OF AGES 1–3	8,300,000	3,800,000	1,500,000
ESTIMATED ABUNDANCE AGE 4	14,500,000	9,000,000	5,500,000

RECENT STOCK ABUNDANCE AND ABUNDANCE PREDICTIONS

Total haddock landings from 4T–V–W in 1967 were 10,912 metric tons (ICNAF Stat. Bull. Vol. 17, 1969), in 1968, 13,309 metric tons (ICNAF Res. Doc. 69/21), Canada landing approximately 75% of the total in each year. Canadian landings in 1969 were 9,305 metric tons. Assuming Canada also landed about 75% of the 1969 catch, total landings were approximately 12,000 metric tons. Applying Canadian catch composition data to total landings, allows these yields to be expressed in numbers of fish, 8 million, 9.4 million, and 7.9 million, haddock being landed in 1967–69 respectively. Using equations 1 and 2, the state of the stock in 1967–69 is portrayed in terms of available population, removals, and recruits (Table 8). Available population declined between 1967–69 from 33 million to 25 million fish, landings were stable at approximately 12,000 metric tons, while F increased from 0.47–0.59.

The state of the stock in 1970–72 depends not only on the abundance of recruits, but on the fishing mortality exerted. Assuming F is 0.50, the value giving maximum sustainable yield under stable conditions, the population may increase slightly to 28 million fish in 1970, and decline to 20 million in 1972. Landings will be approximately 9,000–9,500 metric tons (Table 8).

TABLE 8. 4T–V–W haddock: available population, removals, recruits, fishing mortality (F), and yield, 1967–72.

	CALENDAR YEAR					
	1967	1968	1969	1970	1971	1972
Available popn. x 10^{-6}	33.0	30.5	25.0	27.8	25.6	20.3
Removals x 10^{-6}						
Total	13.2	14.0	11.6	11.2	10.8	9.0
Fishing	8.0	9.4	7.9	6.9	6.9	5.9
Natural	5.2	4.6	3.7	4.3	3.9	3.1
Recruits at age 4 x 10^{-6}	10.0	8.5	14.5	9.0	5.5	?
Fishing mortality F	0.47	0.57	0.59	0.50	0.50	0.50
Landings metric tons	11,000	13,500	12,000	9,500	9,500	9,000

DISCUSSION

Even at the low levels of stock abundance prevailing in 1967–69, fishing mortality remained high. In 1970–72 recruitment will continue to be poor and it is likely that fishing mortality will remain at least as high as 0.50, possibly higher. Thus, it appears likely that stock abundance will show a further substantial decline by 1972, unless further regulatory measures are enforced. Obviously, the most rapid recovery of the stock would be effected through complete cessation of fishing. A catch quota designed to prevent a further stock decline below 1967–69 levels, would necessarily have to be less than 9,000 metric tons.

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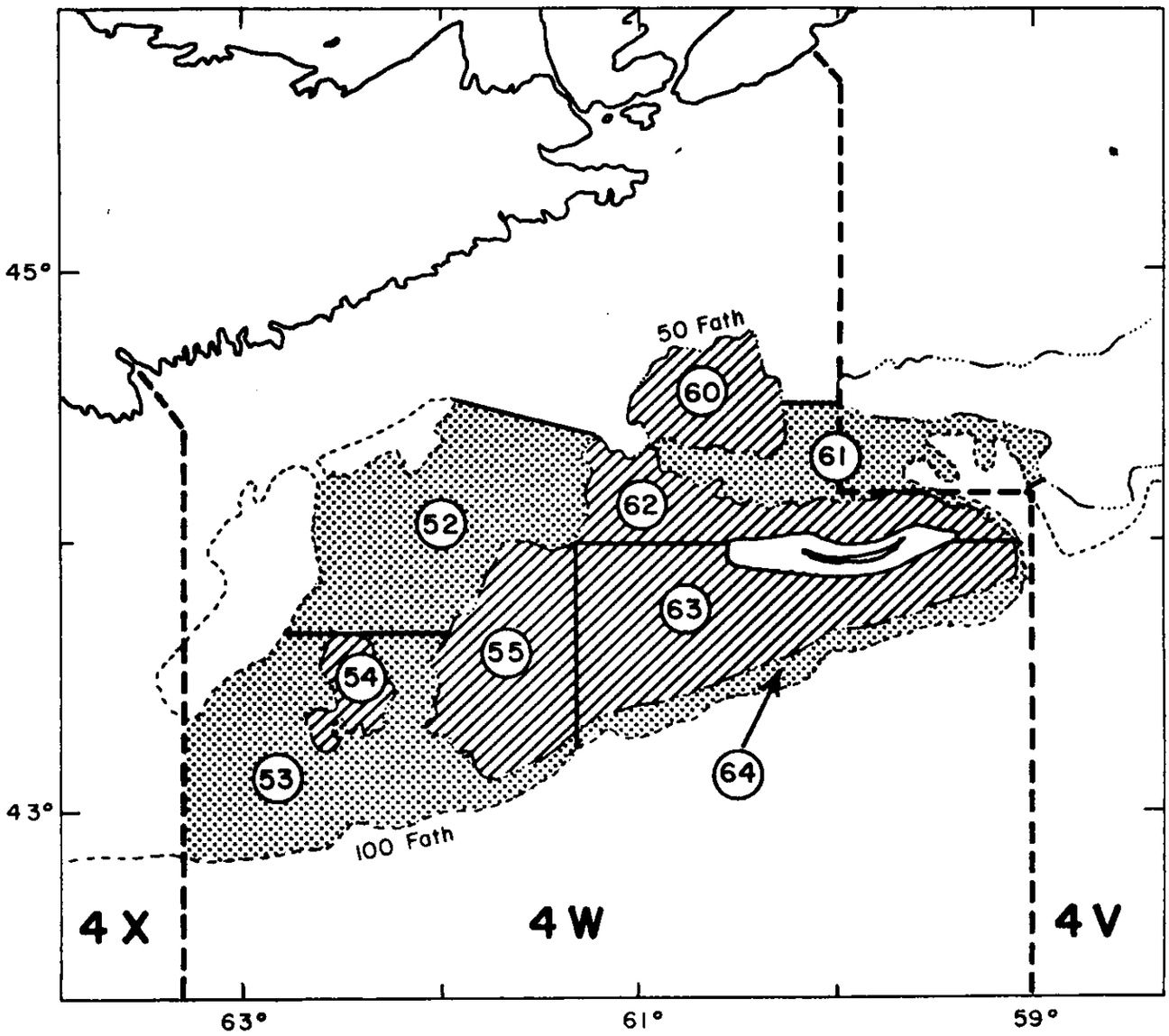

Fig. 1. ICNAF Div. 4W showing strata 52–55, 60–64, used to calculate juvenile haddock abundance.

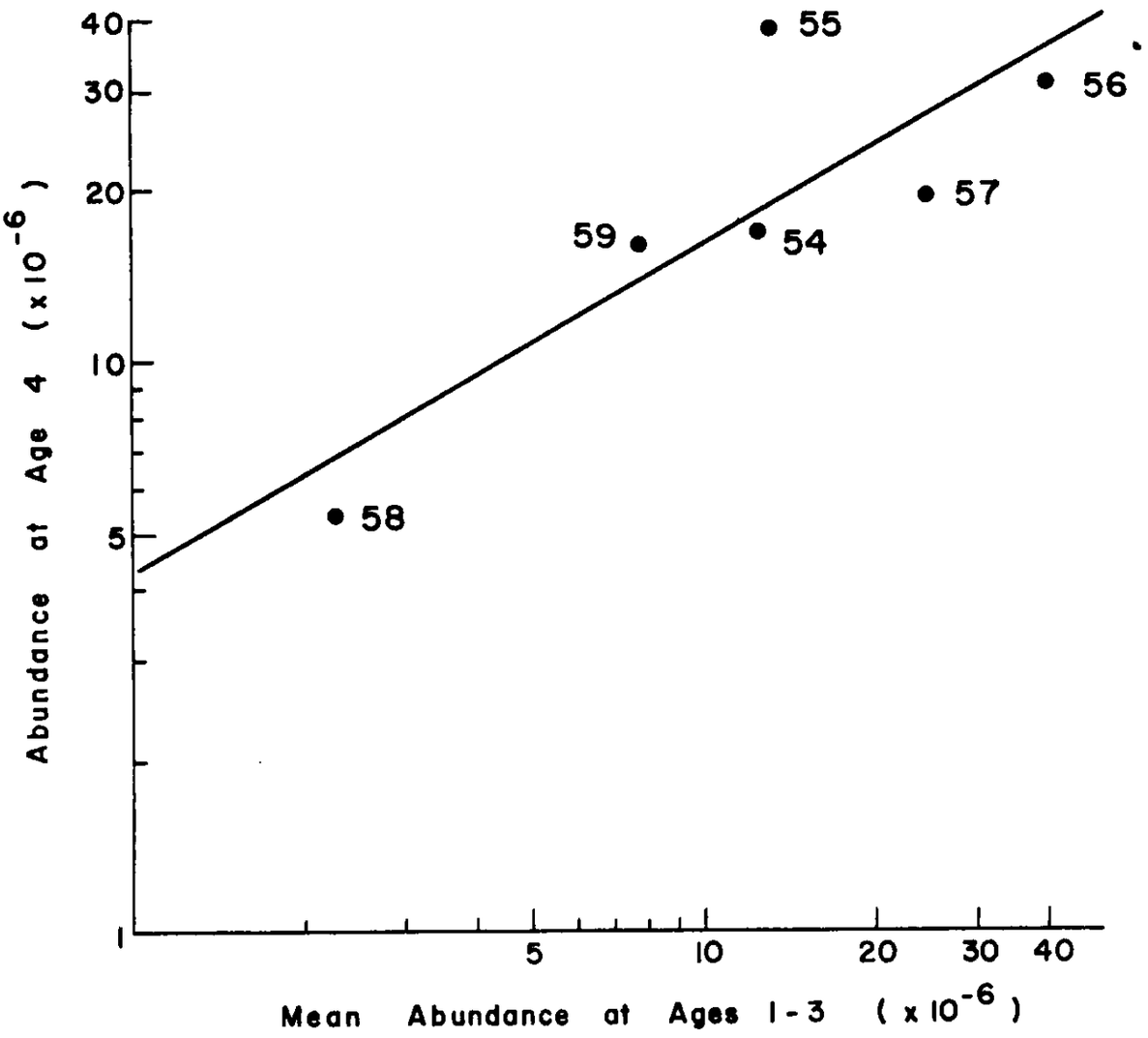

Fig. 2. Relationship of mean abundance at ages 1–3 estimated from survey cruises to abundance at age 4 from commercial statistics for the 1954–59 year-classes.